Appendix E
Methods for Quantification of Greenhouse Gas Mitigation Policy Options

This appendix summarizes key elements of the methodology for quantifying GHG impacts and costs that has been used in the CCAC analysis.

- Common units and results reported:
  - **Net GHG reduction potential** in million metric tons carbon dioxide equivalent ($MMtCO_2e$) using IPCC 100-year global warming potential based on the IPCC *Second Assessment Report.*[1] GHG reductions, relative to the reference case projection of GHG emissions without the options (i.e., business as usual), are reported for 2010, 2020, and cumulatively for the period 2007-2020. Where significant additional GHG reductions or costs occur beyond this period as a direct result of actions taken during the 2007-2020 period, these are indicated as appropriate.
  - **Net present value** (NPV) **cost** (or cost savings) for the period 2007-2020 in 2005 constant dollars, using a 5% real discount rate.[2] Positive numbers represent options with net costs; negative numbers represent options with net cost savings.
  - **Cost per metric ton of CO2 equivalent emissions reduced** (or removed) represented as $\$/MtCO_2e$. This unit of measure represents the 2007-2020 NPV cost associated with a policy recommendation, divided by its cumulative emission reductions over the same period.

- <u>Consistent assumptions and methodologies:</u> In order to ensure consistent results across options and TWGs, common factors and assumptions were used for items such as:
  - **Electricity avoided costs and emissions**: Common values – dollars per Megawatt hour ($/MWh) and tons of CO2 emissions per Megawatt hour (tCO2/MWh) – have been used for avoided electricity costs and avoided emissions respectively. Avoided electricity costs are based on the levelized value of the long-term standard Qualifying Facilities Tariff from the Montana Public Service Commission which is $49 per MWh.[3] Avoided

[1] IPCC (1996) *Climate Change 1995: The Science of Climate Change*. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, eds.; Cambridge University Press. Cambridge, U.K.

[2] Capital investments with lifetimes longer than 2020 are represented in terms of levelized or amortized costs, in order to avoid "end effects."

[3] Estimate derived from contract data underlying the "the long-term, standard QF [Qualifying Facilities] tariff," "Option 1" ($49.90 per MWh, nominal cost average of quarterly contract costs from 2007 through 2014) as set by the Montana Public Services Commission, in an order covering Docket No. D2003.7.86, Order No. 6501f 2; Docket No. D2004.6.96, Order No. 6501f; and Docket No. D2005.6.103, Order No. 6501f, dated December 19, 2006. The $49.90 cost indicated is shown in paragraph 184 of the Montana Public Service Commission (PSC) document. Cost shown here extends the stream of nominal costs in the original Northwestern Energy/ PPL Montana (NWE/PPL) document by including values for 2015 to 2020 that increment the 2014 average value at the rate of inflation, levelizes the resulting 2007 to 2020 stream, and adjusts the levelized value to 2005 dollars.

emissions, for analysis of individual options, is consistent with the state-level inventory and forecast developed as part of the CCAC process. To estimate emissions reductions from the full set of options, an integrated analysis was undertaken. Adjustments were made to the totals in the Energy Supply sector to reflect the aggregated impacts of the integrated analysis.

  - **Fuel costs and projected escalation**: Fossil fuel price escalation has been indexed to USDOE projections as indicated in its 2007 Annual Energy Outlook.
  - **Emission increasing activities**: Some options may involve some increased demand for energy or other potential emission sources (e.g. Combined Heat and Power systems can increase fuel demand in the industrial and commercial sectors). Such direct emissions increases are factored into the analysis.[4]

- Aggregation of impacts: Some options overlap in terms of coverage, both within and across sectors. CCS begins the quantification of options by assuming that an individual policy is implemented in a "standalone" fashion, as if no other new policies are being adopted. Following this, CCS examines the likely interactions of policies assuming they are adopted as a group. For many policies, there are no interactions (e.g., the carbon sequestered by trees does not interact with the effects of increased energy efficiency). In these cases, the quantification of emission reductions and costs for different policies can simply be added together. However, there are numerous cases where one cannot simply add together the impacts associated with two options.[5] In order to avoid double-counting of GHG reduction potential and cost (e.g. more than one option avoiding the same emissions source), interactive effects were estimated where possible, and emission reduction totals reflect these overlaps. In other words, the total emissions reductions for the state are lower than the sum of the results for individual options, as noted in the totals for each TWG.

- Geographic scope and lifecycle analysis:
  - **GHG impacts of policy options are estimated regardless of the physical location of emissions reductions**. For instance, a major benefit of recycling is the reduction in material extraction and processing (e.g. aluminum production). While a policy option may increase recycling in Montana, the reduction in emissions may occur where this material is produced. Where significant emissions impacts are likely to occur outside the

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[4] Some policy options could also result in emissions leakage, either positive or negative. Negative leakage would occur if a policy leads emitting activities to shift to areas outside its target area or increases activity as a result of lowering the cost of service (e.g., the rebound effect). For example, if not considered carefully, policies to protect forest lands could shift forest clearing activities to other regions or states. Conversely, some policy options could result in positive leakage, through replication outside the target area (e.g., by lowering the price or increasing access to lower emitting technologies). Where such effects might be significant, these should be noted qualitatively.

[5] A hypothetical can illustrate this. Imagine the invention of an airplane that improves fuel economy by 50%. If such airplanes replaced the entire current fleet of airplanes, jet fuel consumption (and associated GHG tons) would decrease 50%. In parallel, imagine a "modal shift" policy that decreased demand for air travel by 50%. In isolation, this modal shift could decrease jet fuel consumption (and associated GHG tons) by 50%. However, if these occurred at the same time, the decrease in aviation emissions would *not* be 50% + 50% = 100%. Instead, fuel economy would interact with demand decrease so that aviation emissions would total 25% of their previous level, calculated as follows: (1 – 50%) × (1 – 50%). Thus the "interactive" decrease would be 75%, not 100%.

state, this is indicated. These emissions reductions are counted towards Montana's emission reductions, since they result from actions taken by the state.

  - Related to the previous point, **lifecycle analysis** is applied wherever emissions impacts upstream (e.g., production, extraction) or downstream (e.g. waste disposal) from a specific activity constitute a significant fraction of a policy option's emissions impacts *and* studies are sufficient to enable estimation of lifecycle impacts. For example, lifecycle analysis is used to estimate the emissions benefits of biofuels relative to the fossil fuels that they might displace.

- Transparency: Data sources, methods, key assumptions, and key uncertainties are clearly indicated.

- Cost perspectives and inclusion: The general approach of direct (NPV) cost and cost-effectiveness analysis is used, as widely applied to GHG mitigation policy options.[6] Included are the direct, economic costs from the perspective of the state as whole (e.g. avoided costs of electricity rather than consumer electricity prices). This bottom-up approach is relatively transparent and is capable of reflecting the costs (and cost savings) associated with an individual policy option, in contrast to macroeconomic analysis, which aims to capture flows and interactions across all sectors of the economy.

  Examples of costs included:

  - Capital costs levelized (amortized) where appropriate, e.g. for improved buildings, vehicles, equipment upgrades, new technologies, manure digesters and associated infrastructure, ethanol production facilities, mass transit investment and operating expenses (net of any saved infrastructure costs such as roads),
  - Operation, maintenance, and other labor costs (or incremental costs relative to standard practice),
  - Fuel and material costs, e.g. for natural gas, electricity, biomass resources, water, fertilizer, material use, electricity transmission and distribution, and
  - Other direct costs, administrative costs, and other costs (where readily estimated), such as the grid integration costs for renewable energy. technologies, or the costs of administering an energy efficiency project, or of implementing smart growth programs (net of saved infrastructure costs).

  Examples of costs or benefits not included:

  - External costs such as the monetized environmental or social benefits/impacts (value of damage by air pollutants on structures, crops, etc.), quality-of-life improvements, or improved road safety, or other health impacts and benefits,
  - Energy security benefits,

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[6] See Section 2.4 of the IPCC Fourth Assessment Report, Working Group III, for more discussion of various economic analysis approaches. http://www.mnp.nl/ipcc/pages_media/AR4-chapters.html

- Macroeconomic impacts related to the impact of reduced or increased consumer spending, shifting of cost and benefits among actors in the economy, and
- Potential revenues from participation in a carbon market.